PERFORMANCE AND BEHAVIOR OF CONCRETE ELEVATED WATER TANK UNDER DIFFERENT EARTHQUAKE LOADING

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STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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DEDICATION

This thesis is proudly dedicated to

My loving and supportive parents
Mr. Zamli Bin Md Mahiddin and Mrs. Haslinda Binti Hashim
For their love, pray, care and their gentle soul that had taught me to trust in Allah

My hardworking and respected supervisor
Ir. Dr. Saffuan Bin Wan Ahmad
For his excellent guidance, advices and motivation

My faithful close friends
For supporting and encouraging me to finished my thesis

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ABSTRAK

Kajian ini dilakukan untuk mengkaji tingkah laku seismik bagi struktur tangki air bertingkat konkrit disebabkan oleh pemuatan gempa bumi Acheh dan El-Centro. Struktur tangki air bertetulang tinggi digunakan secara meluas dan dianggap sebagai perkhidmatan yang penting di banyak bandar. Keselamatan dan tingkah laku mereka kritikal semasa gempa bumi kuat kerana mereka menyumbang kepada keperluan penting; air minuman, jika berlaku kebakaran, dll. Oleh itu, struktur ini tidak sepatutnya runtuh supaya ia boleh digunakan untuk pelbagai kemudahan orang ramai. Reka bentuk struktur ini mesti menahan pemuatan gempa bumi kerana Malaysia telah mengalami beberapa kejadian gempa bumi akibat pemuatan gempa bumi yang berlaku di negara-negara jiran terutamanya Indonesia yang telah mendedahkan struktur yang sedia ada kepada risiko yang mungkin tidak dapat menahan pemuatan gempa ini. Banyak bangunan di Malaysia tidak direka mengikut kod yang menentukan peruntukan seismik. Tingkah laku struktur jenis ini diperhatikan kepada model dan menganalisis struktur tangki air bertingkat yang tertumpu kepada beban gempa yang berbeza menggunakan Program SAP2000 dan juga untuk menentukan bentuk mod terbaik analisis getaran bebas. Banyak kajian menumpukan pada tingkah laku, analisis dan rekaan seismik pada tangki, terutamanya dalam tangki tanah. Dalam dekad yang lalu, kebanyakan kajian ini menumpukan pada tangki yang tinggi. Selain itu, kajian ini juga untuk menentukan prestasi struktur tangki air bertingkat konkrit semasa daya gempa bumi terjadi. Semua data beban gempa telah diambil dari Jabatan Meteorologi Malaysia (MMD). Eurocode 8 yang mempertimbangkan peruntukan seismik telah digunakan untuk menganalisis spektrum tindak balas. Dari analisisi ini, kelemahan struktur tangki air bertingkat konkrit dan ciri dinamik akan diperoleh dan digunakan untuk mereka bentuk struktur yang lebih selamat pada masa akan datang.

ABSTRACT

This research is done to study the seismic behaviour of concrete elevated water tank structure due to Acheh and El-Centro earthquake loading. Concrete elevated water tank structure was widely used and considering as important town services in many cities. Their safety and behaviour are critical during strong earthquakes as they contribute for essential requirements; drinking water, fire fighting's in case of fire accidents, etc. Hence, these structures should not collapse so that they can be used in meeting essential needs. The design must resist the earthquake loading since Malaysia have been experienced few earthquake events due to the earthquake loading that occurred in the neighbouring countries especially Indonesia that have expose local existing structure to a risk which may not withstand the earthquake loading. A lot building in Malaysia is not design according to code that specifies the seismic provision. The behaviour of this type of structure is observed to model and analysed the concrete elevated water tank structure subjected to different earthquake load using SAP2000 Program and also to determine the best mode shape of free vibration analysis. Many studies focused on the seismic behaviour, analysis and design on tanks, particularly in ground tanks. In the last decade most of these studies have concentrated upon the elevated tanks. Besides that, this research also to determine the performance of concrete elevated water tank structure during earthquake force. All the data of earthquake load were taken from Malaysia Meteorological Department (MMD). Eurocode 8 that considering seismic provision were used for response spectrum analysis. From the analysis, the vulnerability of concrete elevated water tank structure and dynamic characteristic will be obtained and used for design a safer structure for future.

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LIST OF SYMBOLS

cm	centimetre
km	kilometre
°	Degree
km/s	kilometre per second
M_L	Local magnitude
M_S	Surface-wave magnitude
M_B	Body-wave magnitude
M_W	Moment magnitude
G	Gal
cm/sec/sec	centimetre per second per second
mm	Millimetre
T	Period
f	Frequency
m	metre
m^2/s	metre square per second

LIST OF ABBREVIATIONS

MMD	Malaysia Meteorology Department
MMI	Modified Mercalli Intensity
PGA	Peak ground acceleration
EC	Eurocode
BS	British Standard
L	Love
R	Rayleigh
DL	Dead load
LL	Live load
EL	Earthquake load
RC	Reinforced concrete
FVA	Free Vibration Analysis
RSA	Response Spectrum Analysis
SDOF	Single Degree of Freedom

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Earthquake measuring 7.5 magnitude struck Central Sulawesi on September 28, 2018 has re-created the people's anxiety about the dangers of natural disasters and the fears of such a catastrophe can happen to us. It is a large-scale earthquake and produces large-scale impacts too. Most of buildings have collapsed and many people are trapped in the ruins of the dead or seriously wounded. We need to be grateful that our country is almost free from catastrophic earthquakes. Every time natural disasters occur in Indonesia, such as the enormous earthquake and Aceh tsunami in 2004, the earthquake in Lombok in July 2018, and the latest earthquake in Sulawesi, Malaysians asked the same question whether the earthquake paths are approaching us. The tectonic features that have affected Peninsular Malaysia can be divided into two; the far field earthquakes and the near field earthquakes (Marto, Tan, Kasim, & Mohd.Yunus, 2013).

The entire surface of the earth is dynamic, always moving slowly like the growth of human nail. There is a moving part faster (reaching 8 cm a year). This region produces gigantic magnitude earthquake and is often known as an earthquake lane or some that calls it a Fire of Ring. In Southeast Asia, this line can be dispersed up to 500 km associated with large and very large earthquakes. Its position includes the islands of Sumatra, Java, Bali, Lombok, Nusa Tenggara, Sulawesi and the Philippine archipelago.

The earthquake path is still not change. In terms of geological position and geography, Malaysia is out of this path. Malaysia faces a small and medium scale earthquake. In Peninsular Malaysia and Sarawak, scientific records show that earthquakes are now only very low, just a small shake and no disaster. In Sabah, especially in the Tawau, Lahat Datu and Ranau areas, there have been a number of

moderate earthquakes. Sting causes minor damage, but no death. Most earthquakes in the world occur along the boundaries of the tectonic plates and are called Inter-plate Earthquakes (Design, 2005).

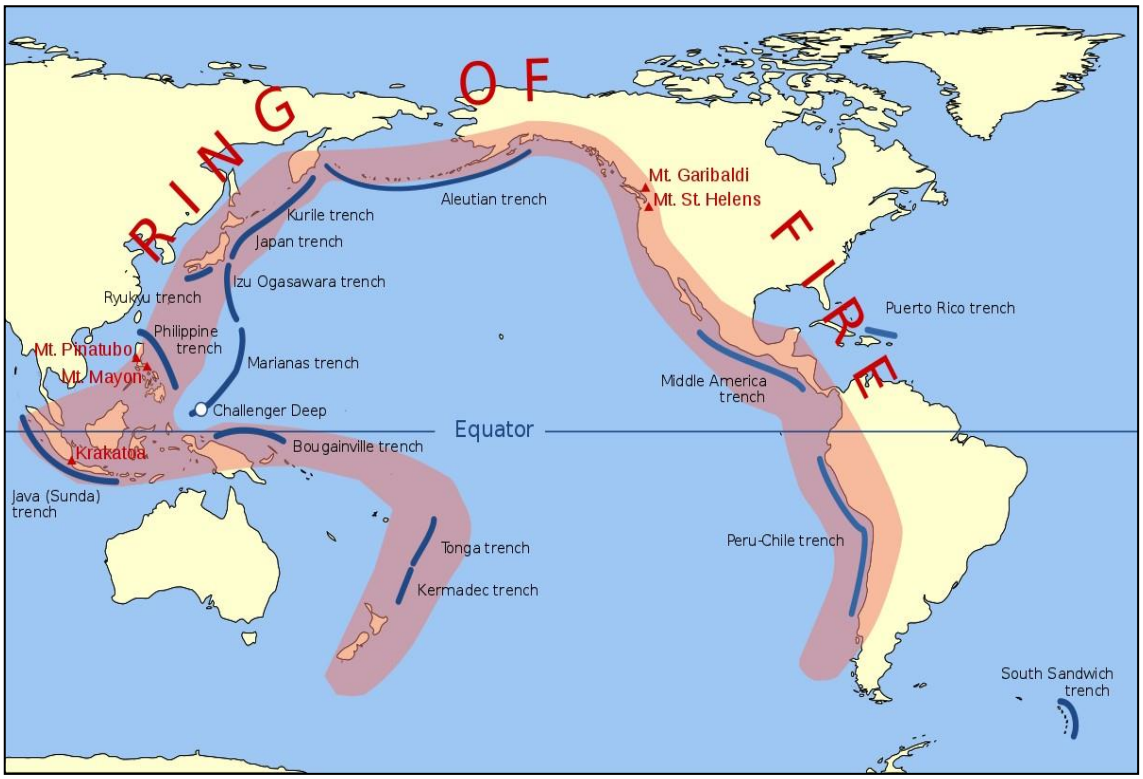

Figure 1. 1 The Fire of Ring

Source: (Marto et al., 2013)

1.2 Problem Statement

Malaysia can be said to be free from earthquake and categorized in low seismicity group (Vaez, Bin, & Zare, 2016), but yet we can feel the tremors at certain places. After encountered several tremors that comes from neighbouring nations, Malaysian begin to make a judgement on the probity of existing structures in Malaysia to resist the earthquake effect. In Sabah and Sarawak, they experienced the earthquake more than the peninsular Malaysia. A 4.0 magnitude earthquake hit the Mount Kinabalu area, some 16 km west of Ranau at about 28 June 2016 on Friday.

Also due to urbanization, industrialization and development happening around the world demand for high-rise buildings has increased day by day (Shejul, 2017). And it has been reported that a lot of buildings in Peninsular Malaysia still in a good

performance and minimum 50% of selected buildings is known to felt or experience the concrete deterioration issue due to the vibration during earthquake. The seismic crisis affected buildings and infrastructures with a total damage besides of fatality. We should consider the vulnerability of the elevated water tank structures to the seismic effect. The building in Malaysia including the elevated water tank should be designed to consider the seismic effect since the minor disaster had already occurred. A lot of structures in Malaysia had been design according to BS8110 which is not considering any seismic provision.

In a real earthquake situation, the first vibration is always subsequent by other vibration. This is the natural behaviour of earthquake and may arise not many hours after the previous one, and may occur constantly to a few days. In engineering view, it also known as repeated earthquake or multi event earthquake. Thus, during a huge earthquake event, structures are imposed to the action of tremors load more than one. The structure may expose to the minor to medium damage after experiencing the first quake resulting in strength and stiffness degradation of the global system. One of the major problems that may lead to failure of these structures is earthquakes (Algreane, Osman, Karim, & Kasa, 2011). If these structures are not repaired, they are expected to having worst damage that lead to collapse. Therefore it is necessity of seismic loading consideration for water tank structure in Malaysia.

1.3 Research Objectives

The main objective of this research is to study the seismic performance of elevated water tank structure due to earthquake while the sub objectives of this research are:

a) To determine the vulnerability of existing critical elevated water tank under earthquake loading.

b) To study the behaviour of elevated water tank under major and minor earthquake loading.

c) To study the dynamic characteristics of elevated water tank under different types of loading.

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